Join in Stuart's Exploits in Lightwave Comms

Stuart Wisher G8CYW introduces his new series in *PW* featuring communications with light. It's many years since *PW* featured the famous *Photophone* project and Stuart has earned a reputation for his innovative approach to lightwave comms. So, off we go!

Welcome to the wonderful world of light wave communication! In the my new series articles I want to introduce you a form of communication that's a lot of fun, doesn't take a lot of skill to build the circuits and doesn't even require a licence! It could give you the chance to join in with other interested people and make some contacts that you may never have dreamed possible!

How's it done? By modulating a beam of light in the same way that a radio transmitter is modulated – only this project doesn't require any expensive, hard-to-find radio frequency (r.f.) devices, or much in the way of test equipment other than a multimeter. I hope to show you simple circuits that are capable of being used for contacts that can span many kilometres.

I hope that these articles will show you how, in a practical way you can take part in a form of wireless communication, and how you can join a growing band of people in many parts of the country exploring this exciting development!

A Lifetime Interest In Light

First, let me start at the beginning; I have spent almost a lifetime, on and off, trying to use light waves to communicate. I won't bore you too much with tales of my attempts to provide an intercom along a sports track at school (didn't work!). Or creeping around at night with lenses and modulated torch bulbs (okay….it worked a bit!).

A few years ago I saw a copy of the **Radio Society of Great Britain**, (RSGB), *Radio Communication Handbook (8th edition)* which had a section on "Laser DXing" at the end of the microwaves section. This really set my interest and enthusiasm alight! Here were tales of deeds and exploits of serious proportions, and from that moment on I have been hooked. You could be too!

As a first step, I then went on an internet quest. You should too, just use your favourite search engine and type in things like "laser dx", "modulated light" "optical communications" and so on. You could also try a few callsigns; **Clinton Turner KA7OEI** in the USA has an amazing website as does **John Yurek K3PGP**. **Yves Garnier F1AVY** in France and **Chris Long VK3AML** in Australia are also worth looking up.

The **Radio and Electronics Association of Southern Tasmania** (REAST), has a website, on which you'll find many reports of their optical activities. I don't have a website – but searching my callsign or name will yield a little of what I have been up to!

One site you must not miss is **Optical Links** run by **Tim Toast** in the USA. You'll need to put this last one on your favourites bar as there is reading material here to keep you going for ever! Tim continually searches the web and posts links here, to everything he finds that is useful and relevant.

Following up one link helped me to make a small discovery and design something new! So I feel that I've contributed a little to this developing light wave communication scene.

Finally, before getting on to the stuff with wires coming out of it, I must mention a Yahoo Group, "UKNanowaves" to which I subscribe. On this you will find day-by-day messages between people interested in building, setting up and using light wave communications gear. There's also a useful files area and several photo albums showing different versions of equipment that have been built.

Please apply to join in – you are all welcome. The moderator who runs this group always likes it when I go and speak at a club or other meeting, generate more interest and cause him to 'Okay' more requests to join in! But that's enough of the adverts – let's get on with the business of exploring in a more practical way!

First Steps

As a first step into this wonderland of new possibilities, I demonstrated to a group of interested friends a modulated low power laser pointer and a simple receiver. This showed that I could project a beam of light carrying a signal over a kilometre or so (This will be the first project to be described in *PW*).

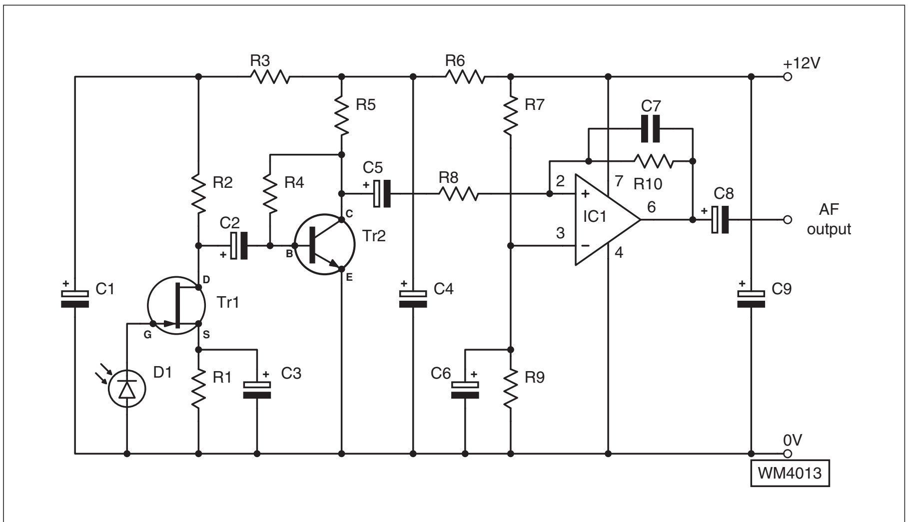


Fig. 1: Stuart's lightwave communications receiver design.

But which came first – the chicken or the egg? In fact, it's actually better to build a receiver first as you can test it using almost anything electrical that gives off light. Streetlights, car lights and even aircraft strobe lights all give off an optical signal that can be received when the receiver is pointed at them – providing a lens is used to focus light from a distant source on to a photo diode in the receiver.

The circuit, (**Fig. 1**) starts with the photo diode converting an amplitude modulated (a.m.) light wave signal into an electrical signal, it's used in its photovoltaic mode which is one of two ways to use this component. (In the photovoltaic mode the photo diode acts like a miniature solar cell and generates a small voltage from the incoming light).

The diode is directly coupled into the field effect transistor (f.e.t.) gate, which biases it as well feeding the signal to it to be amplified. The bipolar transistor that follows it boosts the weak signal further before feeding it into an op-amp amplifier. This circuit works well in the dark and is really just a chain of amplifiers.

The circuit is 'hot'! It must be used in a screened box which is well earthed or all you will hear is a lot of mains hum! I use a small audio amplifier in a separate box based on a LM386 with a loudspeaker to hear the signal aloud – but a small earpiece could be used on the output of the receiver alone.

The screened lead that carries the signal out of my receiver box also carries its power supply from my audio amplifier box. Screened cable is used so no noise is picked up on the power leads. A printed circuit board (p.c.b.) design is shown in **Figs 2**. This circuit will operate from 9V or 12V.

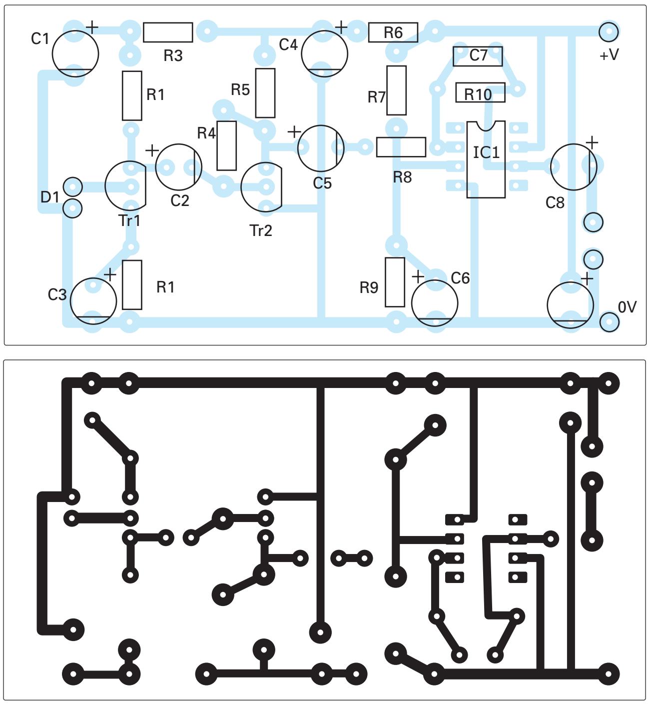


Fig. 2: The lightwave communications receiver printed circuit board design and overlay. As it's basically an audio amplifier, layout is simple.

Earpiece Option?

If you are planning to build the earpiece option, a set of these are available for just £1 (I told you nothing expensive is needed here!), from the shops with almost the same name as the price! The earpieces I used each have a resistance of around 18Ω (they are probably around 32Ω impedance), and I connected both earpieces in series, increasing the impedance to 72Ω which is kinder to the op-amp. This is easily done by connecting to just the tip and the centre band on the jack plug.

A look at the receiver circuit to identify the op-amp feedback resistor (120kΩ) would be useful here, increasing the value of this resistor will give you more gain if you are using the earpiece option alone. A word of caution also here; don't expect to hear much at low frequencies with earphones. Additionally – If you are going with this

Fig. 3: All the mechanical bits needed may be sourced from your local Do-it-yourself store, and pound shop.

option, the battery and a power switch should be included inside the screened box.

The Optical System

The other thing you will need sounds complicated (but isn't) it is an optical system that concentrates the light from a distant source on to the photo diode in the receiver. All you really need is a magnifying glass (the larger the better) mounted at the end of a tube (to keep unwanted light out) and focus an image of the distant light source on to the photo diode. I have a really neat way of doing this, it's not the first thing I built but at beginners level, it's the best!

Currently, at many of the "cheap shops", you can buy a 101mm (4in) diameter magnifying glass made from glass, for a £ or so, a bargain! Hacksaw the handle off (it's plastic, so not difficult) and file the area smooth with the rest of the frame. Then you'll find you can push the lens and its filed frame into some 110mm soil pipe obtainable from major do-it-yourself (DIY) stores. These parts are shown in Fig. 3.

You'll find that you can get several receiver tubes from the shortest length that can be bought, so share with a friend! The precise length of tube that you will need depends on the focal length of the lens.

Incidentally, you will notice that the lens frame isn't quite parallel to the lens axis, and placing the narrow side uppermost on a strong table or the floor will help the next move. Simply push a cut section of the pipe down on to the lens, it's stiff, but when the pipe is level with the floor or table top you will find the lens flush in the end. It won't come out easily – none of mine have ever come to bits after this treatment! I couldn't even get the lens out of the tube for the photograph because it was stuck in so well

Fig. 4: The receiver is mounted with the photodiode in the centre of the rear 'stopper'.

Also available from the DIY store is an end cap and a pipe joiner that I use. The pipe joiner is cut exactly in half and makes a way of connecting the end cap to the lens pipe at the opposite end of the pipe from the lens, use a turn or so of *pvc* insulating tape on the tube so the pipe joiner is a good sliding fit. Important note: the special *pvc* tape is often white and very thin – compared to standard plastic tape.

I use the other half as a lens cap, but you don't have to, I just think it makes the whole assembly look neat. People have confused the assembled telescope for professional equipment! If they only knew!

Cut or drill a hole in the middle of the end cap to give access to the focussed light from the lens and mount the receiver (I used double sided sticky tape!) on the outside of the cap, you can see this in **Fig. 4**. I also cut down the cylinder on the end cap that goes inside the soil pipe to 20mm, this adds to the tube length when working out the tube length required.

Depending on the focal length of the magnifying glass (mine are 275mm), you will need this distance between the centre of the lens and the active surface of the photodiode, allowing for the lens to be pushed flat in the tube, this makes the tube length some 260mm. All this without any nuts and bolts!

In my case, further trips to the DIY store revealed wall clips for the pipe to connect it to a tripod-mounted spirit level to complete the job. The laser level and tripod mounts available in the

Fig. 5: A cheap laser level tripod makes an ideal mount and pointing system for repeatable angular alignment between stations.

Fig. 6: The cheap monocular is an ideal way of locating the distant stations modulated light. The simple lens system means that pointing accuracy is less critical.

cheap shops or DIY stores are good buys also, spot all this in **Figs 5** and **6** along with my use of half a pair of binoculars as a sighting aid.

Two Transmitter Options

You have two options when it comes to the transmitter. My original transmitter was based on a low power laser pointer – but there's an alternative of using an ordinary ultra-bright 5mm light emitting diode (l.e.d.) instead.

If you want to use a laser, a good one to use is the type that is fitted into the end of a spirit level. The tripod, mounting head and laser level being available cheaply in various supermarkets or DIY chains.

A laser pointer will need a stable mount and some aiming device. This will make it possible to accurately direct it safely over a path that you've carefully checked out in advance so that there's no possibility of any danger to anyone – and with some end point that will limit the range of the beam. When experimenting with a laser, I used a path over a field that ended in a dense hedge.

If you opt for the l.e.d. approach, then another lens and lens tube etc will be required to produce a focussed beam over your initial path. You should aim to project a focussed image of the l.e.d. on a distant wall to check you have the beam focussed.

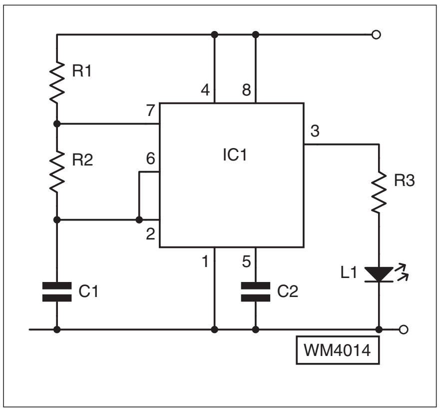


Fig. 7: A quick and simple audio square wave oscillator driving a laser diode is ideal to test out the system. It can be modified to become a more powerful keyed transmitter.

'Water' clear ultra bright l.d.s are the types to go for. They will be much easier to aim and safer to use than a laser since the beam spreads out more as it travels. Most of my future designs are based on l.e.d.s rather than lasers – since l.e.d.s can be modulated linearly. Lasers can't really be modulated with analogue signals; at a low voltage, the laser doesn't lase at all and at a high voltage, the laser melts!

Simple Circuit

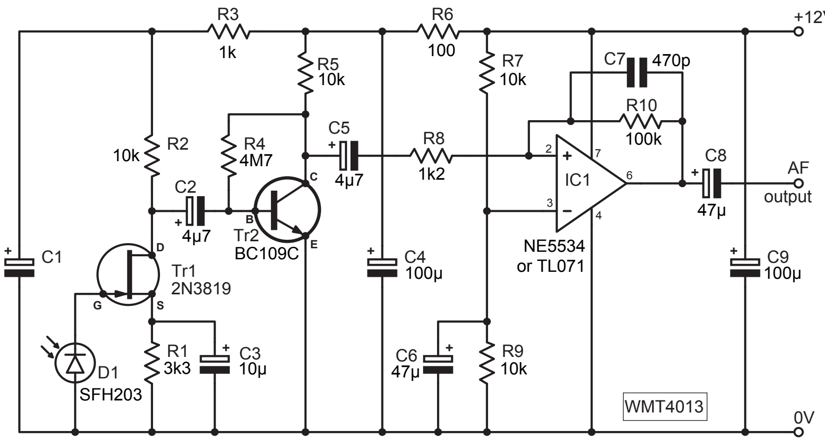
The transmit circuit could not be simpler, a 555 timer i.c. is used as a pulse generator on a frequency around 700Hz (or your preferred tone for listening to). This is adequate to pulse the laser or l.e.d. as both need around 30mA or so. In this mode, the timer i.c. simply produces a square wave signal to switch the output device rapidly on and off. The 555 timer can produce up to 200mA output current so it is not stressed in this application.

The circuit is shown in **Fig. 7** is simple enough to be built on a small piece of stripboard or even on a solderless breadboard (In fact I built it in this way). The l.e.d. or laser will be stressed to destruction if you don't use a large enough series resistor. You have been warned!

All that remains is for you to set the transmitter up over a safe path at night and see how far you can make it go! Next time, I will show you how you can transmit your voice over the link using either the l.e.d. or laser, two different circuits will be described. For those of you who want more power, I will also introduce you to the world of power l.e.d.s and how to drive them. ●

Exploits in Lightwave Communication Part 2

Stuart Wisher G8CYW presents Part 2 of his series, focusing on a different aspect of communications!



Editorial up-date: Due to production difficulties in Part 1, we produced the circuit diagram of Fig. 1 without component values. We have reproduced it again this month and have included the component values. See also the circuit below left. My apologies for the mistakes. **Rob G3XFD**.

Welcome again to the wonderful world of lightwave communications! Last month I showed you how to modulate a low power laser pointer or light emitting diode (l.e.d.) with an audio frequency tone, and a receiver circuit that could pick up the signal. If you built the circuit, how far did you get the signal to travel?

When I did this test, I set up my first trial with some friends using the laser from home over a safe 1km path to a local hill. When we got to the top of the hill, we couldn't see the laser signal at first. Switching on the receiver (it had no lens at this stage), made it plain that we weren't far away from the beam as there was already a tone coming out of the receiver loudspeaker.

Following the increase in sound level soon led us to the beam itself, which at 1km had already spread out to a patch of red light, roughly 150mm diameter, that made my light coloured jacket glow! At this distance the light had now spread itself out and was safe to view. It was the brightest thing visible from that direction. The receiver went into overload when placed in this patch!

I had chosen this path carefully for safety and for the fact that it skimmed over the top of the hill by a metre or so. It was in an otherwise deserted country park and then continued for some distance to another hill where it 'buried' itself safely in a hedge.

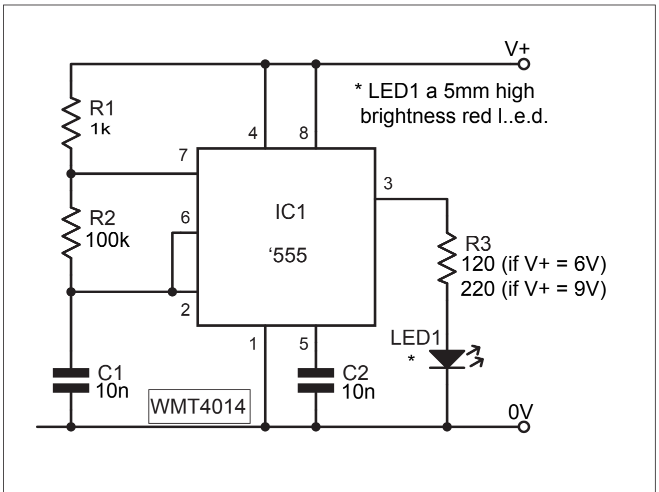
Travelling further to this more distant point, some 2.5km from home now, revealed we were still getting a good strong signal with no lens in front of the photo diode. It was strange to see that the light from the 1mW laser was much brighter than street lamps or even car headlights pointed in our direction!

I went on later to test over a 6km path to another safe site in the countryside and I could still just hear the tone in the receiver with no lens. I did this test at dusk, just as the streetlights some 2km away were switching on and you can see what I saw here in **Fig. 2.1.**

About half an hour later, it had gone properly dark and the signal was even stronger. More streetlights were switched on, some quite powerful lights amongst them, all were outshone by the laser which now has a halo around it due to the camera setting, you can see the effect in **Fig. 2.2**. This shows the need to choose a safe path if you try this project. Yet when I took ten paces either side of the best signal, nothing was visible.

Your Voice On Beam!

On to this month's circuits – and let's get your voice on to the beam! If you want to use an l.e.d. and maybe even thinking of using a high power l.e.d.



This was Fig. 7 of the first part of this project, also published without circuit values, due to production errors.

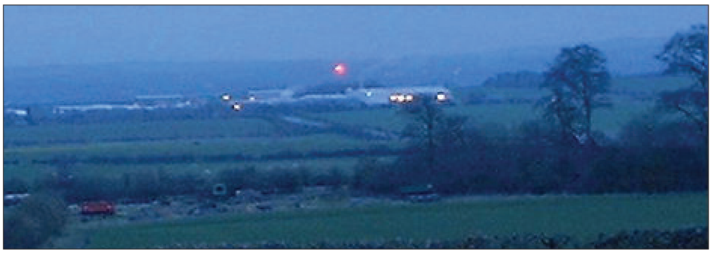


Fig. 2.1: Photograph showing how bright the l.e.d. was at a distance – just before dusk.

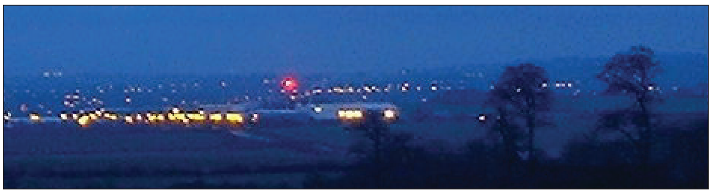


Fig. 2.2: The brightness level of the l.e.d. follows the voltage level from the microphone signal directly.

(more later!), you might wish to consider making the linear amplitude modulated (a.m.) transmitter described next.

It's quite a simple circuit using only two semiconductors. It will not work with a laser which, at best, is only capable of some 15% modulation. If you want to continue using a laser pointer instead of an l.e.d., a laser modulator is shown later in this article.

The first circuit simply converts the microphone signal into brightness variations of the l.e.d. With no audio signal the l.e.d. is at half brightness, the microphone signal will make the l.e.d. peak up to the maximum brightness on positive speech peaks and down to almost zero on negative peaks.

Take a look at **Fig. 2.3**, which explains this; the brightness level of the l.e.d. follows the voltage level from the microphone signal directly. This is known as "baseband amplitude modulation (a.m.)" by the large number of people who are already having fun by making 'optical contacts' between high points in various parts of the country.

All On One Chip!

The first part of the circuit originally used no less than three op-amps until I realised you can get all these functions from one integrated circuit (i.c.)! How's that for value for money!

The i.c. – IC1 – amplifies the microphone signal (about 5mV) up to around half a volt. The input components C3 and R3 form a high-pass filter to reduce unwanted low frequency signals. The feedback components C5 and R4 reduce unwanted high frequency signals, so only the voice bandwidth of 300Hz to 3kHz is amplified to any great extent. If that were not enough, the potentiometer VR1 shifts the voltage level of the output signal for the next stage. All this from the one op-amp!

The voltage level of the signal from IC1 is shifted to enable its output voltage to bias Tr1 correctly so that the l.e.d. is at half brightness when there is no audio input. The transistor Tr1 is an emitter follower that acts in a linear mode to follow the output voltage from IC1 accurately and provide enough current to drive the l.e.d. correctly.

The circuit of the baseband a.m. transmitter is shown in **Fig. 2.4.** I built this on a solderless breadboard in less than an hour, see **Fig. 2.5.** A printed circuit board (p.c.b.) design and overlay diagram are shown in **Fig. 2.6**.

Don't forget that you will need to use a lens as described in the first article to focus the light from the l.e.d. to get this to work over any real distance! I used

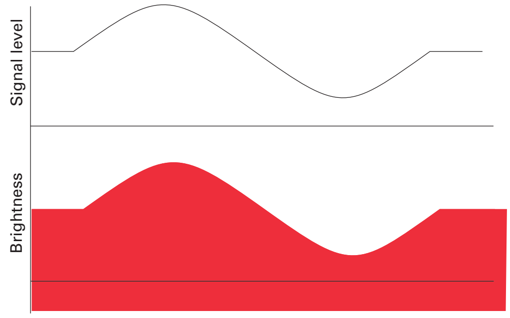


Fig 2.3: Showing direct a.m. modulation of the l.e.d. current and brightness.

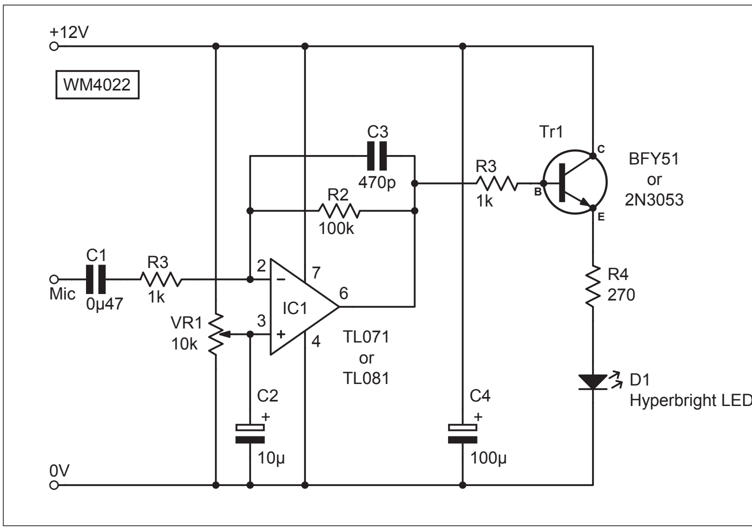


Fig. 2.4: The circuit of the a.m. modulator for driving the l.e.d. brightness directly.

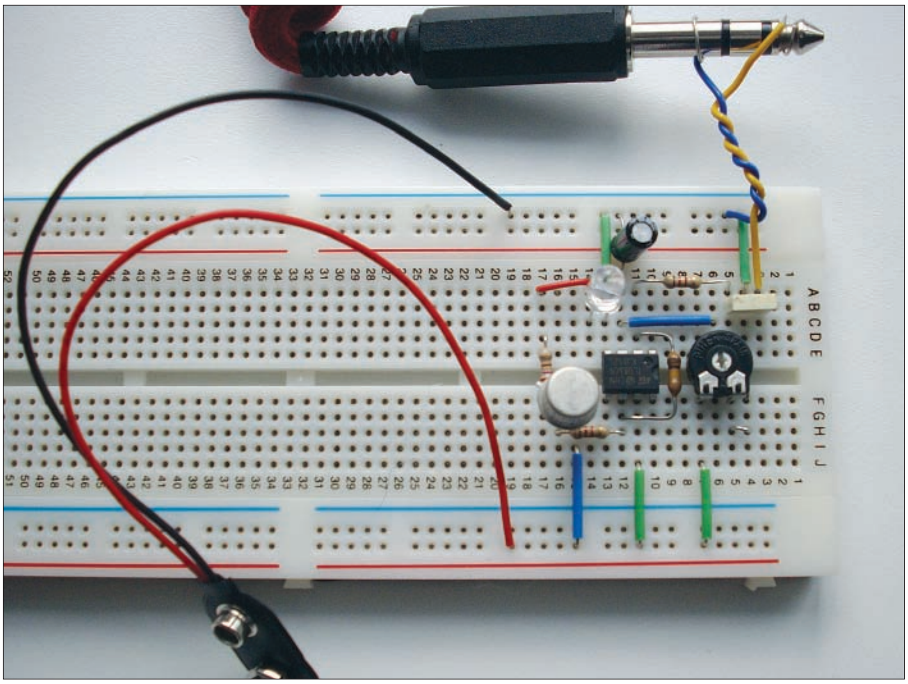


Fig. 2.5: The initial 'lash-up' of the a.m. modulator took very little time to assemble.

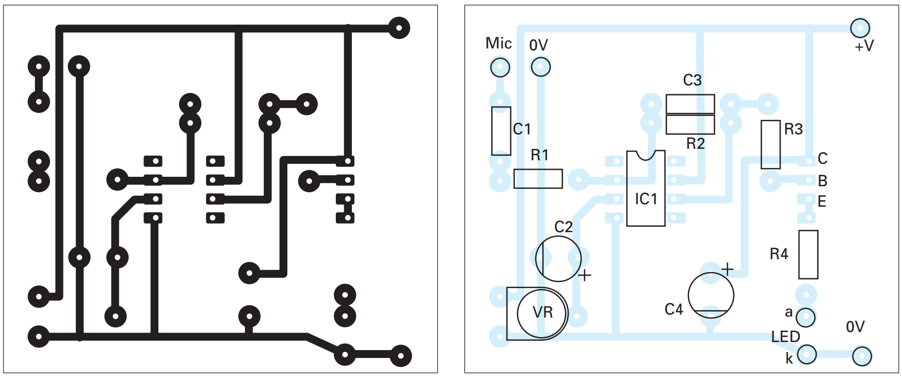


Fig. 2.6: A p.c.b. Track and component overlay for the a.m. Modulator.

a Toshiba high efficiency red l.e.d. type TLSH180P obtained from Maplin, order code PF07H, which has a narrow beam of just 8°, this provided me with good communications over more than 100m with no focusing lens!

It is also possible to reduce the value of the l.e.d. series resistor depending on the maximum rating of the l.e.d. you use. The l.e.d. specified above has a maximum current rating of 50mA and the resistor was reduced to 100Ω to give a useful increase in power output, but be careful!

Circuit For 12V

The circuit is designed to operate from 12V but will work well at reduced power from 9V. It can be set up by adjusting VR1, just set the l.e.d. to be at half brightness with no microphone connected. There should be around half of the power supply voltage measured between the emitter of the transistor and 0V. The microphone signal, when connected, will cause amplitude modulation of the l.e.d. current.

You should see the light from the l.e.d. flicker when you speak into the microphone. If the l.e.d. flashes noticeably brighter when you do this, you may need to increase the setting of VR1 slightly.

The best test here is to listen to the transmitted audio using your receiver as too low a brightness setting may give a little distortion on speech peaks (troughs actually, the l.e.d. may be switching off on the negative peaks of the signal if you set the bias too low). Get this operating correctly and you are ready to go!

The Second Circuit

The second circuit I am going to show you was originally designed to drive the laser diode which can only be modulated by on-off pulses, but it will work equally well for the l.e.d. since it too can be switched on and off very rapidly. Pulse width modulation (p.w.m.) is used to feed the on/off pulses to the output device at a rate well above the highest frequency audio signal to be transmitted.

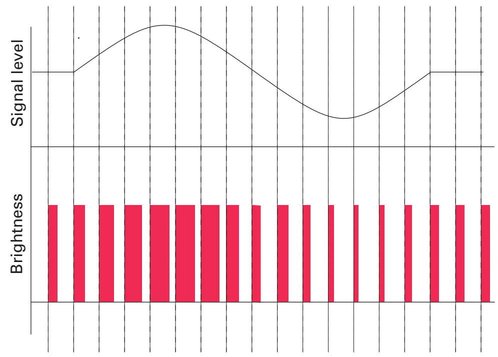


Fig. 2.7: When driving a laser diode, you will need to use pulse-width modulation, to vary the overall brightness.

The width of each pulse is controlled by the circuit to represent the amplitude of the audio modulating signal from the microphone. With no audio input, the p.w.m. circuit generates pulses which spend equal times on and off, this is called a 50% duty cycle.

When the audio signal voltage goes positive, the pulses get longer and the gaps between pulses get shorter, the duty cycle goes above 50%, so the duty cycle is said to increase. Negative input signals cause the reverse to happen and the duty cycle to go below 50%.

My circuit generates pulses at about 20kHz, this is known as the pulse repetition frequency (p.r.f.). This is shown in **Fig. 2.7**, try to follow how the pulse width on the bottom graph (in red, we are using a red l.e.d. or laser after all), follows the audio signal voltage on the top graph.

The circuit of the p.w.m. modulator is shown in **Fig. 2.8.** It works like this, IC1, the 555 timer i.c. generates a saw tooth waveform across the timing capacitor C1. This spends most of its time charging up from around one third to two thirds of the power supply voltage and then rapidly discharging back to one third.

The waveform is actually a capacitor charging curve rather than a linear saw tooth but it's close enough for our purposes. Unusually, the output signal is taken from the capacitor rather than the usual output pin.

The second i.c., IC2, performs exactly the same function as IC1 in the a.m. baseband transmitter circuit in **Fig. 2.4**, (it's the same circuit after all). Integrated Circuit IC2 amplifies and filters the microphone signal. It shifts the d.c. level of its output signal to the correct voltage to operate the next stage.

The i.c., IC3, another op-amp, acts as a comparator with the output signals from the previous two stages as its inputs. It's this stage that effectively outputs a high voltage signal – as long as the sawtooth wave input from IC1 is greater than the amplified and filtered microphone signal from IC2.

As soon as the signal from IC2 is the greater, the output drops to almost zero volts. This happens thousands of times per second and converts the analogue input signal into a p.w.m. digital signal. Since IC3 can't provide enough current to drive the laser or l.e.d., Tr1 acts as a simple switch, boosting the current from IC3 to that needed to drive 30mA or so into the output device. A p.c.b. design

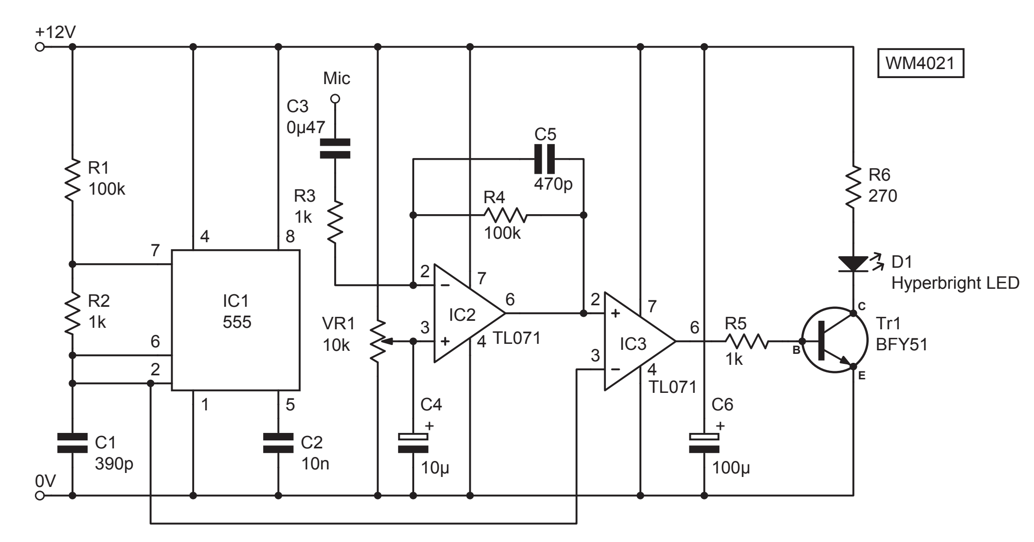


Fig. 2.8: A circuit suitable for use as a pulse-width modulator for a laser diode or a hyperbright l.e.d.

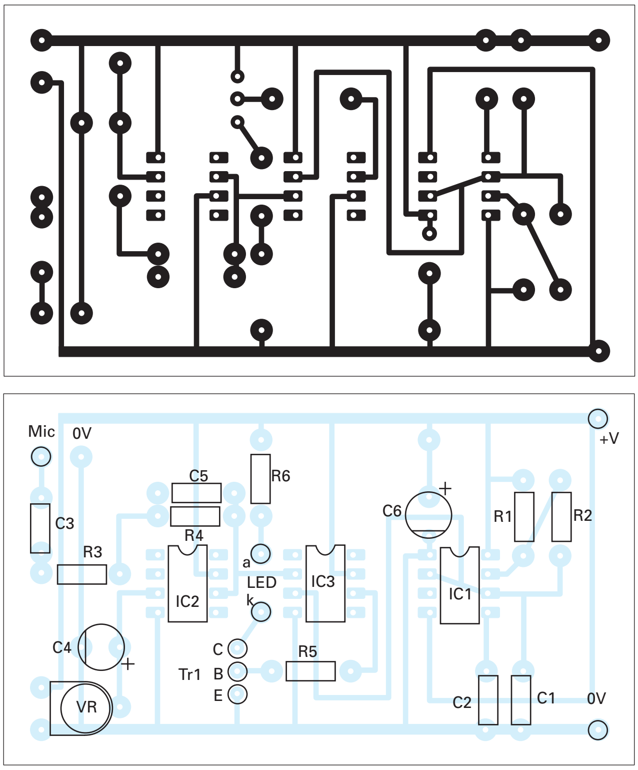


Fig. 2.9: A p.c.b. and component overlay for the pulse-width modulator circuit of Fig. 2.8.

and component overlay for this circuit are shown in **Fig. 2.9.**

Setting Up

To set up the described circuit, with no audio signal, simply adjust VR1 to get the appearance of the l.e.d./laser to be half as bright as the maximum that can be seen at one end of the potentiometer travel. If you have a multimeter that reads duty cycle or an oscilloscope then you can set up the circuit to give 50% duty cycle with no audio input. Then once again you are ready to go!

Using the receiver from last month's article, speech at the transmitter microphone should sound strong and clear when aiming the beam from the l.e.d./laser at the photo diode. Using an amplifier and loudspeaker after the receiver gives a better result and if you're testing at close range you might even overload the receiver!

When my group of friends and I experimented with the type of circuits I've described, we found that contacts up to 6km were made with ease! It was possible with careful alignment to more than double this distance! Beyond that, it became increasingly difficult to either aim a laser accurately, or the low power l.e.d. was running out of steam! We decided higher power was needed!

High Power Diodes

There are several high power l.e.d.s currently available, ranging from 1W up to over 4W, this may seem strange if you have only used the 5mm or so through-hole variety, but they're not expensive and easily available from the usual suppliers.

My favourite type for red light are made by Osram, I have also had a lot of success with the Golden Dragon 1.4W series, but these have been superseded by the Platinum Dragon range which are rated at 3.4W. These are surface mounted devices that need to be mounted on a thin piece of p.c.b. on a heat-sink because they can be run at up to 1A peak! I'll leave it to you to imagine just how much brighter these are than conventional l.e.d.s!

Driving The Diode

To drive one of these l.e.d.s is better done using one of the currently available power m.o.s.f.e.t.s. I use the IRF540 which is specified to handle much more current than the l.e.d.s needs. Mounting it on a heat-sink, particularly for the linear a.m. circuit is another good idea.

For the linear a.m. circuit, it's only necessary to replace the bipolar transistor with the m.o.s.f.e.t, the base connection becomes the gate of the m.o.s.f.e.t., the collector becomes the drain and the emitter becomes the source. The l.e.d. is then replaced by a Platinum Dragon l.e.d. on a heat-sink as shown in **Fig. 2.10**.

The l.e.d. resistor needs careful choice, start with a 22Ω 4W wire wound resistor which can be reduced later down to 8.2Ω if you set up the bias very carefully. You should aim for no more than 0.5A current flow to the whole circuit with no audio input (most of it goes through the l.e.d. and should only be allowed to peak up to 1A on speech peaks!).

Equally Possible

It's equally possible to use the power l.e.d. for the p.w.m. circuit, replacing the bipolar transistor, l.e.d. and series resistor, but to set this up you need to choose a suitable value for the resistor. Don't touch the variable resistor this time as that affects the duty cycle; once set up, it should be left. Start with a 22Ω 4W resistor as above and work your way down to a lower value with extreme care!

That's it for now, using the lower power Golden Dragon l.e.d. my friends and I eventually made successful two-way contacts over distances of up to 32km! Using more advanced circuits, light wave contacts have now been made over distances in excess of 100km! Good luck with your efforts and let me know how far you get! ●

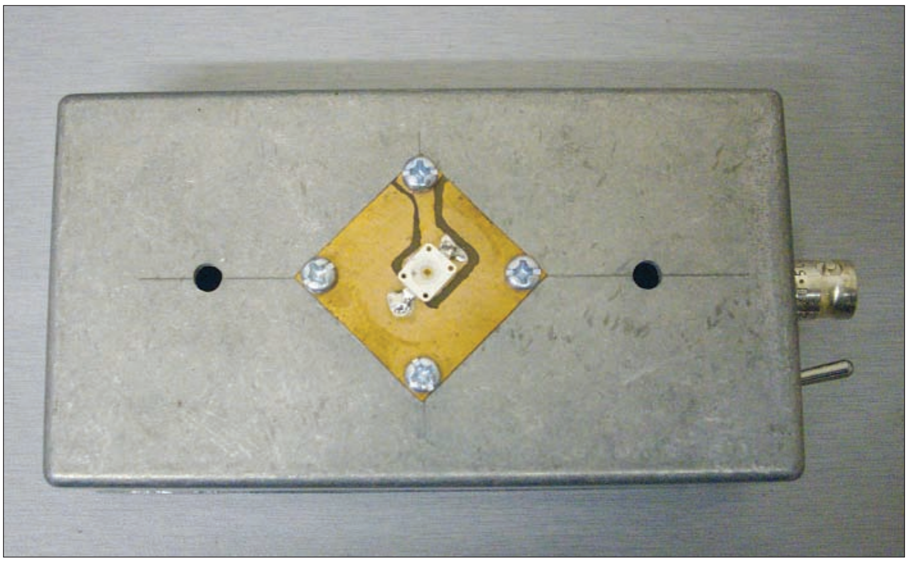


Fig 2.10: Higher power l.e.d. need suitable heat-sinks as shown here for a 1.4W device.

Exploits in Lightwave Communication Part 3

Stuart Wisher G8CYW continues sharing his exciting adventures using optical communications by presenting some more ideas for *PW* readers – and Roger Lapthorn G3XBM is already joining in!

Light-beams and 430MHz systems at the ready for '/P' operation.

Welcome yet again to the wonderful world of lightwave communication! In Part 2, I showed you two ways of modulating a low power laser pointer or light emitting diode (l.e.d.) with a microphone signal.

Much to my pleasure – I got word that after the first article, one enthusiast – none other than *PW* author **Roger Lapthorn G3XBM** – had the receiver built and running just a few days after the issue came out! Roger has built lightwave receivers before and he was kind enough to say this one was a few dBs better (his words) than his own, thanks Roger!

Before I get started on technicalities this month, I must mention Rob's build up to article one, where he mentioned the *PW Photophone* from long ago. This came at a good time as I have been researching the history of optical communication and I've recently constructed a replica of my 1967 attempt which must have been prompted by *PW* back in those days. I was trying to provide communication from one end of the 100m athletics track to the other when I was at school. People kept tripping over telephone wires laid on the ground and breaking them, and walkie talkies were illegal in those days, so I thought "what about a light beam?"

The Transmitter Circuit

The transmitter circuit I used was little more than an audio amplifier and a filament light bulb (yes a small light bulb is capable of being modulated by an audio signal!). The amplifier, from the Harverson Surplus Company (see the original advert in **Fig. 3.1**), used transformers as was normal in those days, and a 15Ω output winding that I simply placed in series with a suitable lamp and the amplifier power supply, a 9V battery.

The audio signal then got superimposed on the battery voltage and it worked quite well. I used a bicycle headlamp reflector to concentrate the light in the desired direction!

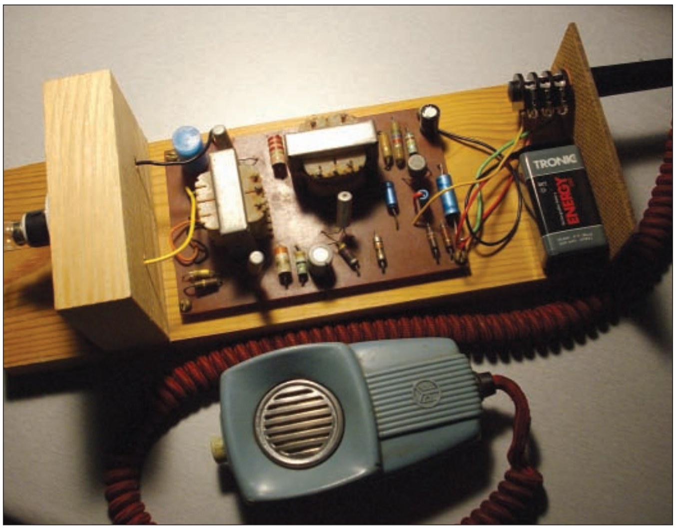
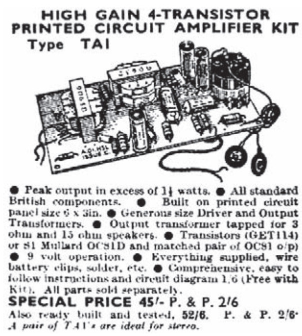


Fig. 3.2: A reworking, many years later, of the original light-beam transmitter.


HIGH GAIN 4-TRANSISTOR PRINTED CIRCUIT AMPLIFIER KIT
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● Peak output in excess of 1¼ watts. ● All standard British components. ● Built on printed circuit panel size 6 x 3in. ● Generous size Driver and Output Transformers. ● Output transformer tapped for 3 ohm and 15 ohm speakers. ● Transistors (GET114) or 81 Mullard OC81D and matched pair of OC81 o/p) ● 9 volt operation. ● Everything supplied, wire battery clips, solder, etc. ● Comprehensive, easy to follow instructions and circuit diagram 1/6 (Free with Kit). All parts sold separately.

SPECIAL PRICE 45/- P. & P. 2/6

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A pair of TAI's are ideal for stereo.

Fig. 3.1: Stuart G8CYW originally tried using this ready-built amplifier to modulate a small torch bulb, with limited success.

Since I **still** have the amplifier in my junk box, (a little worse for wear, and missing some of the circuit board I'd sawn it off!), I restored it and mounted it in true 1960s fashion on a piece of wood with brass screws and a hardboard front panel. You can see this in **Fig. 3.2**.

The circuit worked surprisingly well when I tested! It is a pity that I couldn't get the whole system to work in 1967! It must have been the receiver that caused the problem!

I have already had an offer of a OC71 and plan to scrape the paint off it to make it into a phototransistor, that's what you did in those days if you couldn't afford a proper OCP71! I've another ancient audio amplifier in the junk box – so a replica receiver should also appear soon!

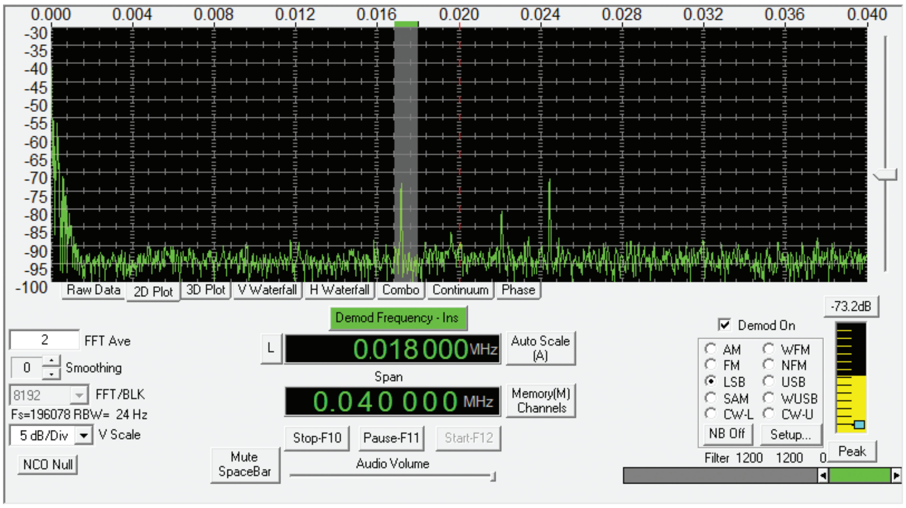

Fig. 3.3: A screengrab of the audio 'hash' from modern lighting systems' switch-mode power supplies.

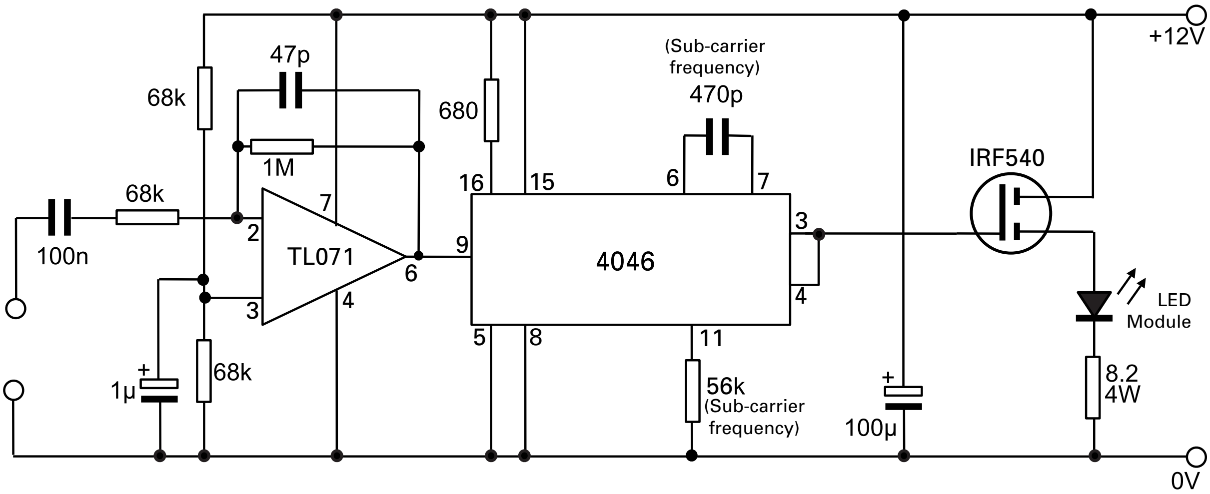

Fig. 3.4: The circuit diagram of the f.m. transmitter that offers improvements over an a.m. version.

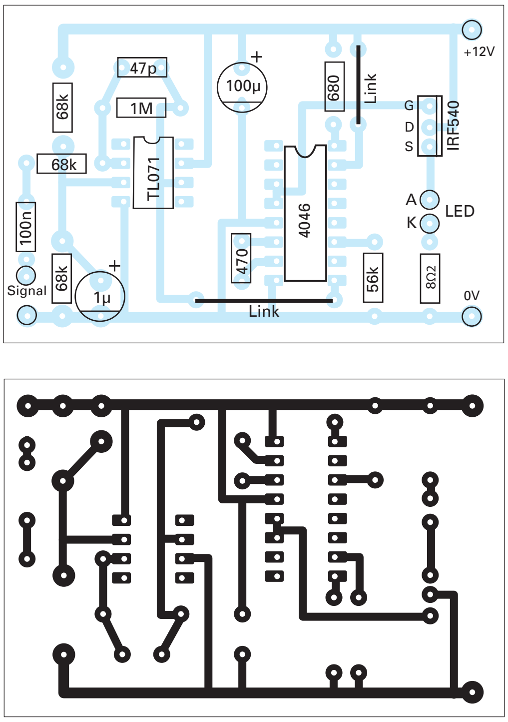

Fig. 3.5: A suitable layout for the f.m. transmitter of Fig. 3.4.

Back to the future, (well it was then!), when we tried out the circuits described in parts one and two of this series, we found that amplitude modulation (a.m.) signals on light behave exactly the same as a.m. signals do on radio, the further away from the transmitter, the weaker the signal, and the more the noise (QRN and QRM) builds up by comparison.

There's plenty of QRM on lightwaves from street lights, etc., and the QRN from the sun in the daytime (and even the moon at night) was thought to severely reduce the possible range. Another effect we noticed when working distances of over 10km (6 miles or so) was the twinkling appearance that all lights have at distance (it's called scintillation).

The latter effect produces a rumbling or rustling effect on the received audio that gets worse as the distance increases. When we tried to operate near some particularly bright overhead lights once, the a.m. signals were lost completely, the receiver was saturated by mains hum. So, you may ask – how could we overcome this?

Frequency Response Curve

I'd previously looked at the frequency response curve of an optical receiver designed by **Mike Groth VK7MJ** and seen that its response continued in frequency to 50kHz. This gave me an idea, why not try to transmit a frequency modulated (f.m.) sub-carrier signal above the audio frequency (a.f.) spectrum where all the QRM was generated?

Any street lamp running from the mains will produce a strong 100Hz signal and at distance, street lights connected to all three phases of the mains produce a 300Hz signal and strong lower harmonics of this all over the 300Hz to 3kHz a.f. communications bandwidth. Worse still, modern discharge street lamps near my home QTH scream away at 800Hz and harmonics of this, not to mention the growing number of high power l.e.d. street lamps now being fitted.

I have a screenshot from my software defined radio (SDR IQ in my case) connected to an optical receiver. This shows QRM extending from low audio frequencies up to the region of 2kHz, almost completely affecting the required audio spectrum **Fig. 3.3**.

The screenshot covers the frequency range from 500Hz to 40kHz, I was receiving my beacon signal at 17kHz (in the grey rectangle) from a distance of 15km at the time, the other spikes are low frequency (l.f.) radio signals that leak into the receiver, despite screening. You might be able to gain an idea of the problem!

The scintillation of distant optical signals, referred to earlier that results in continual variations in the amplitude of the received signal would also be less important in an f.m. demodulator with a limiting amplifier stage. The solution then

seemed to be to go to f.m. on around 20kHz.

Simple FM Transmitter

The f.m. transmitter I've designed is quite simple, it's based around the voltage-controlled oscillator (VCO) in a 4046 integrated circuit (i.c.). This is biased with a variable voltage signal from an op-amp.

The op-amp also serves as a microphone amplifier and audio band-pass filter as well in my usual quest to squeeze the ultimate in function and value-for-money as you have noticed from my earlier articles! The 100nF microphone coupling capacitor in series with the 68kΩ op-amp input resistor together form a high-pass filter that progressively reduces the response below about 300Hz. The 47pF capacitor across the 1MΩ feedback resistor forms a low-pass filter that progressively cuts unwanted treble frequencies.

The output stage shown is a m.o.s.f.e.t. capable of driving a high power l.e.d. at currents around 1A. The m.o.s.f.e.t., power l.e.d. and resistor should be mounted on a suitable heat-sink as shown in the previous article.

In practice, I prefer leaving the m.o.s.f.e.t. in the transmitter box and using its box as its heat-sink, and then using a small die-cast box for the l.e.d. and its resistor, mounted up behind the lens tube using coaxial cable to connect the two boxes together as I described in my last article.

If you want to drive a lower power l.e.d. or a laser pointer – you should then simply use a bipolar transistor instead of the m.o.s.f.e.t and a higher value resistor to limit the current to a safe value as shown in the previous article. This circuit will also work well with a laser as it produces a square wave output. With the component values given, the operating frequency is just over 20kHz and well away from the QRM I described earlier.

The circuit is shown in **Fig 3.4** and a printed circuit board (p.c.b.) design and layout as **Fig. 3.5**.

If you used a large box for your a.m. transmitter, there may be room inside for this transmitter also. It would result in some economy of components as you will only need one microphone socket (wiring this to both microphone inputs does no harm – I did it!) and one m.o.s.f.e.t. output stage (which would require a switch), but then you'll have made a dual-mode optical transmitter!

Note: I'm not suggesting other op-amps aren't suitable (my personal favourite is the NE5534 as it is a low-noise amplifier as well as having a good bandwidth, and only costs a little more). These op-amps are all pin for pin compatible. Just don't try using a 741, these are from the electronic stone age and have really had their day! This first stage is needed to selectively amplify the 20kHz f.m. signal that'll appear at the output of the a.m. receiver board and bring its amplitude up to a suitable level for the f.m. demodulator. If the received signal is already strong, the amplifier will saturate and act as a limiting amplifier, just what we need! Its action tends to even out a scintillating signal by removing amplitude fluctuations.

However, back to the multiple-feedback amplifier, with just a few resistors and capacitors you've an amplifier tuned to around 20kHz with no tuning! Again the value for money theme is present! The components in the transmitter and receiver have been chosen so that both will work on the same frequency with only one adjustment in the receiver to peak up the response!

That's it For Now!

I've run out of space for now, so next month I'll be describing the f.m. receive adaptor and demodulators for f.m. and the building of suitable circuits. If you have any queries or suggestions – please contact *PW* and your E-mails will be redirected to me. See you next time! ●

Exploits in Lightwave Communication Part 4

Time to focus on receiving the lightwaves!

Stuart Wisher G8CYW continues sharing his exciting adventures using optical communications by presenting some more ideas.

This month I'm going to focus on the optical receiving side. If you're following this series by constructing the circuits, there's no need to go on producing one receiver after another as I did, seven times over!

Instead, this time I'll describe a frequency modulation (f.m.) adaptor that will happily go on the end of the receiver described in article one – but with one small but important modification to its circuit. The f.m. adaptor relies on the extended frequency response the a.m. receiver will have when its op-amp feedback capacitor is removed. This can be seen in Fig. 1 on page 28 of the March 2013 issue of *PW*.

Originally, C7 was used to limit the frequency response of the circuit to the communications bandwidth and remove noise at frequencies above 3kHz or so. If you've already constructed the printed circuit board (p.c.b.), just clip one of the capacitor leads where it enters the board making it easy to replace should you ever need to, failing that you can always remove it completely and use it in the f.m. transmitter circuit!

Without C7, the response of the receiver goes strongly into the higher audio frequency (a.f.) range and beyond, above 20kHz. Just make sure you've not added any other capacitors to roll off the frequency response to reduce any audio hiss on a.m. or you'll prevent it feeding the higher frequency range out that'll be needed by the following stages!

The First Stage

For the first stage of the f.m. adaptor, I used an interesting op-amp based circuit that behaves as if it were a tuned amplifier! This is known as a multiple-feedback amplifier, it uses the same type of op-amp you've seen in my earlier designs, the TL071 (or TL081).

That's not to say other op-amps are not suitable (my personal favourite is the NE5534 as it is a low-noise amplifier as well as having a good bandwidth, and only costs a little more). These op-amps are all pin-for-pin compatible. Just don't try using a 741, these are from the electronic stone age and have really had their day!

The first stage is needed to selectively amplify the 20kHz f.m. signal that'll appear at the output of the a.m. receiver board and bring its amplitude up to a suitable level for the f.m. demodulator. If the received signal is already strong, the amplifier will saturate and act as a limiting amplifier, just what we need! Its action tends to even out a scintillating signal by removing amplitude fluctuations.

Back to the multiple-feedback amplifier! With just a few resistors and capacitors you've an amplifier tuned to around 20kHz with no tuning. Again the value for money theme is present!

The components in the transmitter and receiver this month have been chosen so that both will work on the same frequency with only one adjustment in the receiver to peak up the response! For the final stage in the receiver I tried several f.m. demodulators (Foster-Seeley and Ratio types) before I settled on the phase-locked loop (p.l.l.), which I find genuinely has the best performance as well as being the simplest and cheapest to construct. I used the the NE565 integrated circuit (i.c.), there's a single variable resistor in this part of the circuit to adjust for optimum once you have a transmit signal to test it with.

The Circuit Diagram

The circuit diagram for these two

There were some mistakes that crept into the third part of this series that impacted the circuit diagrams and p.c.b. layouts. For the new diagram please E-mail: **info@pwpublishing.ltd.uk** with "Lightcomms Updates" as the subject text. My apologies for this. Editor.

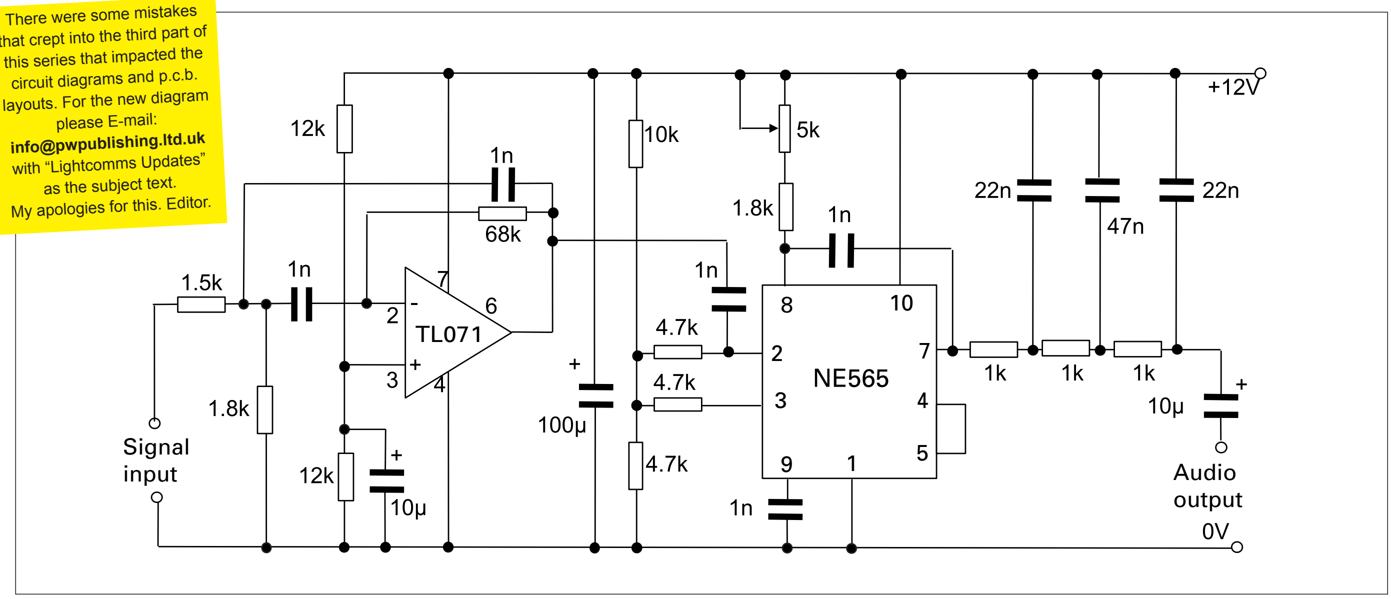

Fig. 4.1: A simple low frequency f.m. Receiver circuit used by Stuart in his experiments.

Stuart G8CYW makes some minor changes to the set-up and rig.

Brian Fothergill G8KPD and his rig in foreground, with Stuart and Nick Peckett G4KUX in background.

stages is shown in **Fig 4.1**, and p.c.b. and its component layout are shown in **Fig. 4.2**. There's a choice here in mounting the f.m. board, I squeezed it in the same screened box with the existing a.m. receiver and put a switch in the circuit so I could either output the demodulated a.m. signal or the f.m. receiver, creating a dual-mode receiver!

If you are using a separate audio amplifier and loudspeaker, the f.m. board could equally well be located in the amplifier box. It's your choice.

How Do They Compare?

So how well does sub carrier f.m. compare to baseband a.m. in practice? The answer is – for the sake of a little more circuit complexity (in the receiver really, the transmitter circuits are comparable), you can get an improved quality of signal, rather like the quality of a local 144MHz f.m. contact.

My friends and I set up a trial to test the f.m. receiver at the location I've mentioned before. It's near some particularly bright overhead lights where the a.m. signals were lost completely and the receiver was saturated by mains hum, at a distance of some 15km (nearly 10 miles) from transmitter to receiver.

Switching to f.m. was a revelation, clear, noiseless signals were heard, Eureka! The idea to switch to sub carrier f.m. was clearly demonstrated to be a valid one.

Trials Set-up

Rapidly, I set up some trials to investigate how far f.m. communications would go. Notable contacts made on f.m. first of all increased the distance to the region of 32km (20 miles) where a clean, fully quieting signal was received, using the 1W Golden Dragon red l.e.d. and the 4in lens.

We later extended the range in stages to an amazing contact of no less than 90km (56 miles) between a high point in the Durham Dales and a point on the North York Moors. Here several of us used our own rigs and made clear contacts over this distance!

However, I'll have to add, that by that point we had found some larger lenses that give more gain on transmit and receive and I'll tell you more about this next time.

One photograph, above left, shows my gear as we set up for the Durham Dales test contact. You can see my double lens set-up, mounted on the only four-legged tripod in the world! (home-brew to the end!) and the 70cm antenna we used for talk-back.

Another view of us on this contact is shown in the photograph, above right. There is a sound file of my contact to **Rob Swinbank M0DTS** on the UKNanowaves Yahoo Group you may wish to listen to. Good luck with your own exploits!

Flushed with Succcess

After being flushed with the success of my a.m. and f.m. Modules, I got to think,"I wonder how single sideband (s.s.b.) would work?" The next thought in my mind was, how was I going to develop an easy way to produce and receive an s.s.b. signal on light? Did I really have to design and build the complex circuits to do this, just to try out a hunch that the major mode used on Amateur bands for DX voice communication might be worth trying on lightwaves?

Then came my brainwave, or lateral thinking, call it what you will. Many Amateurs already have a rig that can

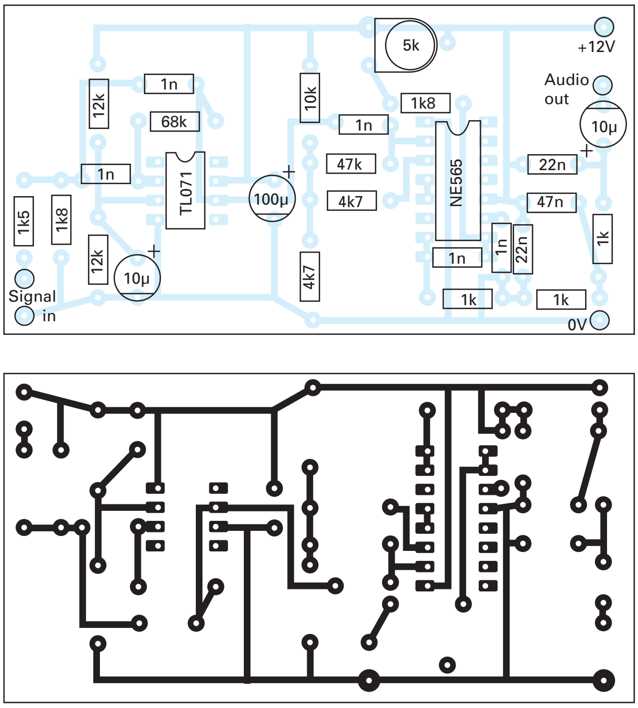

Fig. 4.2: The track pattern and overlay of Stuart's f.m. adapter.

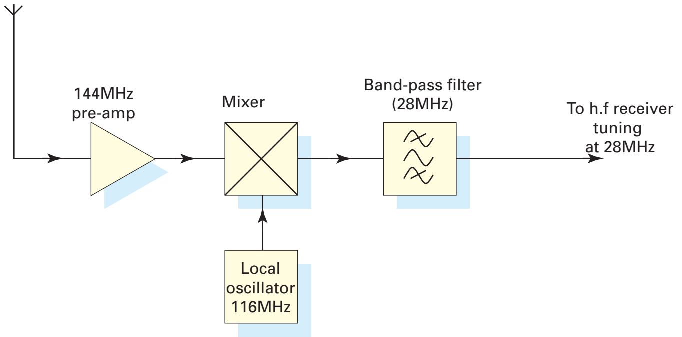

Fig. 4.3: The block diagram of a 2m receive converter with an output in the 28MHz band.

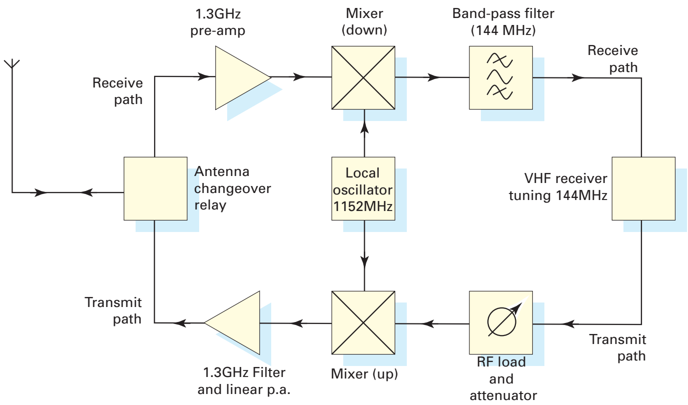

Fig. 4.4: Transverting a 2m rig's input and output to operate in the 1.3GHz (23cm) band means a bi-directional convertion of signals.

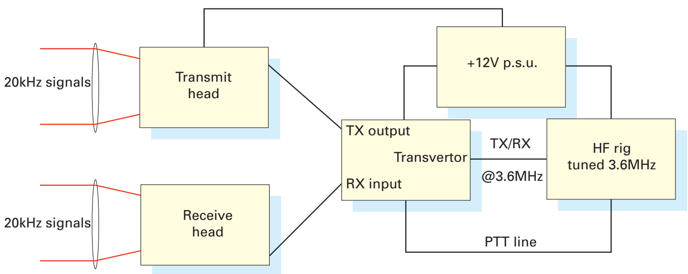

Fig. 4.5: Due to the very low working frequency of the optical transmission, a local oscillator has to be within the working band that the rig is tuned to.

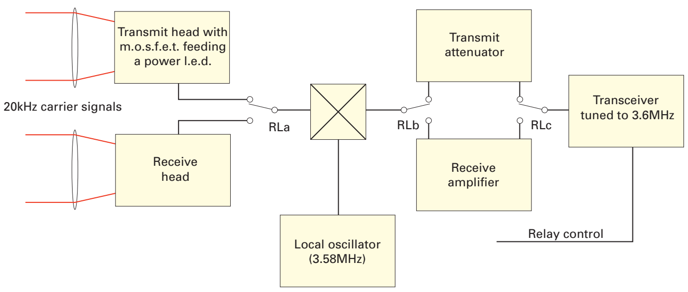

Fig. 4.6: A little more detail of the 3.5MHz to light-beam system that Stuart proposes to use.

receive and transmit s.s.b. (and often a.m. and f.m. too), even if it is just a tiny thing like my Yaesu FT-817, that can receive and transmit low power (QRP) signals, why not use that rig? And so the idea of the "Optical Transverter" was born!

I think I need to go back to basics here to explain this, so here goes. The idea of a transverter is not new. In the past, people bought a "Converter" to put in front of an h.f. receiver to be able to listen to signals on 2m (144MHz) or 70cm (432MHz), by tuning across the 10m (28MHz) band for example as shown in Fig. 4.3. This converter would have a local oscillator feeding a mixer to convert v.h.f. or u.h.f. signals down to a frequency range that an h.f. rig could receive.

It wasn't long before it occurred to someone that this idea could be made to work on transmit also, converting the h.f. signals from a transceiver up to the v.h.f. or u.h.f. range for transmission. So the idea of the "Transmitting Converter" came into being. This was a bit of a mouthful, and the contraction "Transverter" gained popularity.

Nowadays, v.h.f. and u.h.f. transceivers have become commonplace, but the transverter is still with us, used mainly these days for enabling v.h.f. rigs to operate on microwave frequencies, as has been recently shown in *PW*.

See **Fig. 4.4** for a block diagram of a transverter which will convert a 144MHz (2m) rig to operate on 1.296GHz (23cm). These transverters are generally used to increase the frequency range that can be used for communication. But there's nothing to stop a transverter being made to decrease the frequency range! I thought I could use this idea to make my h.f. rig effectively receive and transmit on the very low sub-carrier frequency range (around 20kHz) I found to be very useful for f.m. communication as I explained in the last article.

A bit more planning was needed before I set to work. Which h.f. band to use? What power level from the h.f. rig would be required? What to use as a local oscillator? and finally, what mixer to use? With all this buzzing around in my head, I looked around for the very simplest, most economic (oh, all right then! Cheapest!) solution.

I hit upon the idea of using the 3.5 to 3.8MHz (80m) band from the h.f. rig, which would then mean that a local oscillator within this band would be required **Fig. 4.5**. The local oscillator needs to be stable and it's usual for this oscillator to be crystal controlled. As it happens, there's a commonly available very cheaply available 3.579545 MHz crystal available (it's used in dual tone medium frequency, (DTMF) encoders for phones and often found in junk!)

Let's call the crystal frequency 3.58MHz for simplicity! I don't bother to adjust the crystal to its precise frequency so that's near enough! All that's needed is to make a crystal oscillator circuit for which I used a logic i.c., and the spare gates in the same i.c. also provided the receive-transmit switching, several functions from one i.c. and a cheap solution as you might expect from my designs!

Receive Head & Lens

The transverter needs a receive head (and lens) which converts the incoming optical signal into an electrical 'receive input' signal, (the one I described in articles one and two will do fine) and an l.e.d. and series resistor (and lens) which converts the 'transmit output' signal from the transverter into an outgoing optical signal (again the one from article two will do fine). Of course, the h.f. rig is required to connect to the transverter. This is all shown in Fig. 4.6, but I'm afraid you'll have to wait until next time to see more detail, and to hear of how I got on! ●

Exploits in Lightwave Communication Part 5

Continuing from his last article in the July issue of *PW*, Stuart Wisher G8CYW continues looking at the different techniques for generating optical transmissions and receiving them. In part 5, amongst other important considerations, Stuart discusses his 'Optical Transverter' system.

Welcome once more to the wonderful world of lightwave communications! In the July issue of *PW* in Part 4, I showed you how I took things to another level by using a sub-carrier frequency (at just above the audible frequency spectrum), to carry a frequency modulated (f.m.) signal on a light beam. This neatly side-stepped the problems of QRM and fading (scintillation) experienced on long paths using amplitude modulation (a.m.).

You may think this series is beginning to sound more like radio as it goes along! And for those of you wondering why there is so much of this technology in *PW*, this article goes further down this particular route! In fact, there's a term "radio over light" which fits the way I have developed this form of communication.

I then got to think, after I'd tried a.m. and f.m., I wonder how single sideband (s.s.b.) would work? The next thought in my mind was, how was I going to develop an easy way to produce and receive a s.s.b. signal on light? Did I really have to design and build the complex circuits to do this, just to try out a hunch that the major mode used on Amateur bands for DX voice communication might be worth trying on lightwaves?

Stuart's Brainwave!

Then came my brainwave, or lateral thinking – call it what you will! Many Amateurs already have a rig that can receive and transmit s.s.b. (and a.m. and f.m. for that matter), even if it's just a tiny thing like my Yaesu FT-817, that can receive and transmit low power (QRP) signals. So, why not use that? And so the idea of the "Optical Transverter" was born!

However, at this stage I think I need to go back to basics here to explain this. So here goes!

The idea of a transverter isn't new. In the past, people bought a "Converter" to put in front of an h.f. receiver to be able to listen to signals on 144MHz (2m) or 432MHz (70cm), by tuning across the 28MHz (10m) band for example. This converter would have a local oscillator feeding a mixer to convert v.h.f. or u.h.f. signals down to a frequency range that an h.f. rig could receive. See Fig. 4.3 (p24 *PW* July 2013) for a block diagram of a 144MHz receive converter with an output in the 28MHz band.

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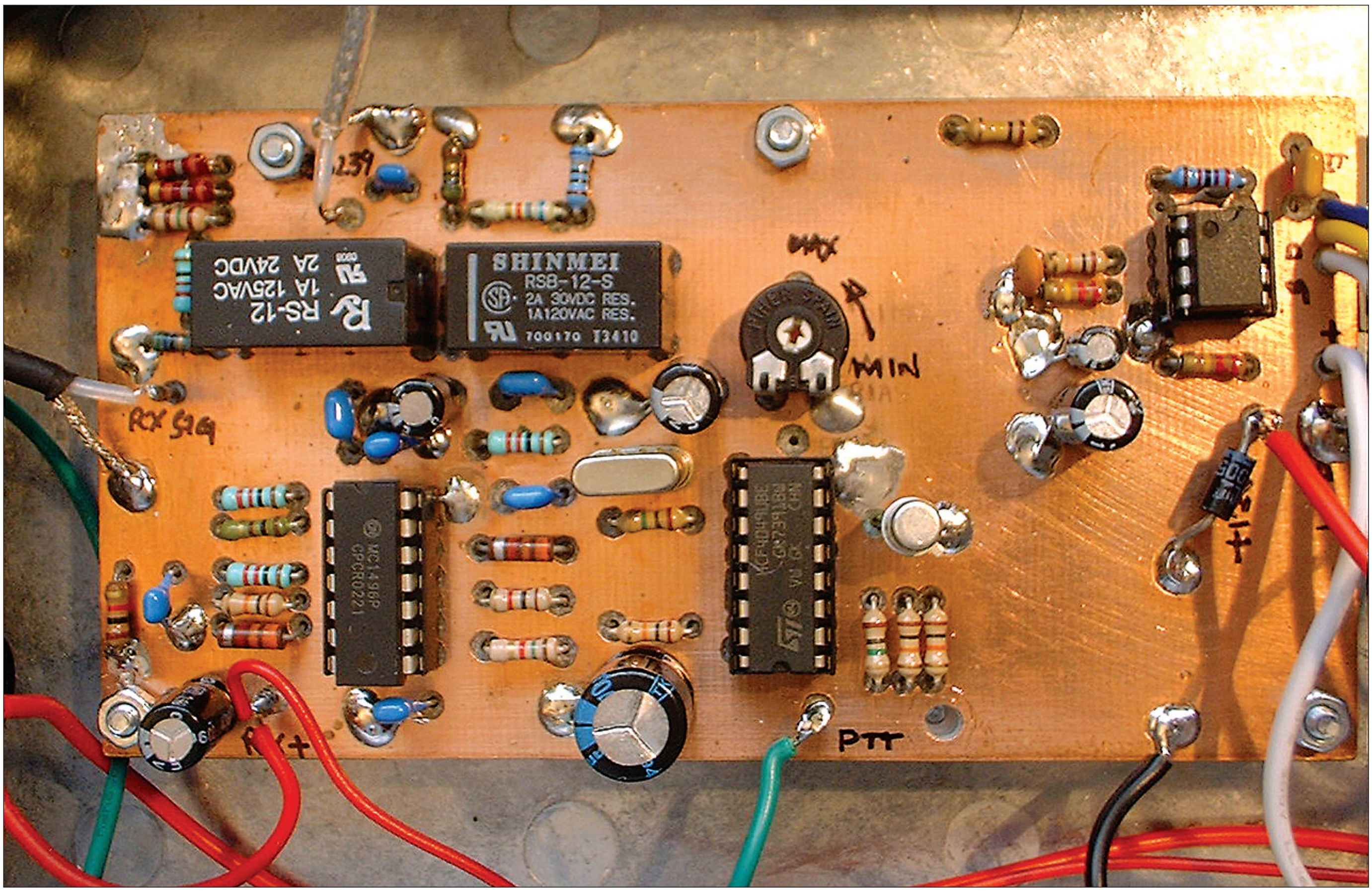
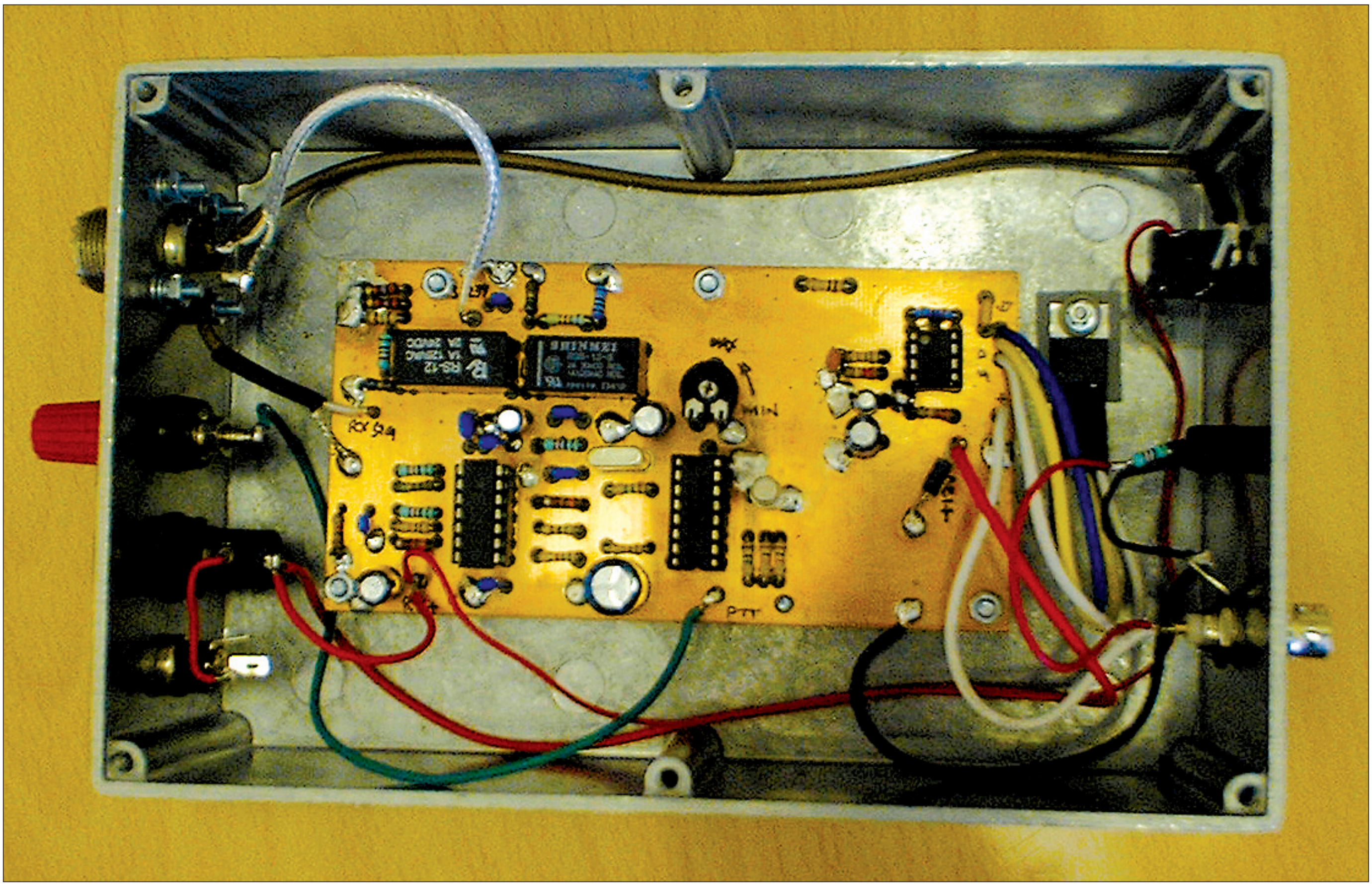


Brian Fothergill G8KPD constructed this early version of this circuit built following the layout presented later.



The die-cast box is used as the heatsink for the m.o.s.f.e.t. driver stage.

someone that this idea could be made to work on transmit also, converting the h.f. signals from a transceiver up to the v.h.f. or u.h.f. range for transmission. So the idea of the 'Transmitting Converter' came into being. This was a bit of a mouthful, and the contraction 'Transverter' gained popularity.

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More Planning Needed!

A bit more planning was needed before I set to work. Questions such as; Which h.f. band to use? What power level from the h.f. rig would be required? What to use as a local oscillator? and finally, what mixer to use?

With all this buzzing around in my head, I looked around for the very simplest, most economic (oh, all right then, cheapest!) solution!

I hit upon the idea of using the 3.5 to 3.8MHz band (80m) from the h.f. rig, which would then mean that a local oscillator within this band would be required. The local oscillator needs to be stable and it's usual for this oscillator to be crystal controlled. As it happens, there's a commonly available very cheaply available 3.579545MHz crystal available – it's used in dual tone medium frequency (DTMF) encoders for phones and often found in junk!

Let's call the crystal frequency 3.58MHz for simplicity! I don't bother to adjust the crystal to its precise frequency – so that's near enough anyway! All that's needed is to make a crystal oscillator circuit for which I used a logic integrated circuit (i.c.), and the spare gates in the same i.c. also provided the receive-transmit switching. Several functions from one i.c. and a cheap solution – as you might expect from my designs!

The Head & Lens

Before I go on to tell you how it all works, the transverter needs a receive head (and lens) which converts the incoming optical signal into an electrical 'receive input' signal, (the one I described in articles one and two will do fine) and a light emitting diode (l.e.d.) and series resistor (and lens) which converts the 'transmit output signal from the transverter into an outgoing optical signal (again the one from Part 2 will do fine). Of course, the h.f. rig is required to connect to the transverter. (This is all shown in Fig. 4.6 (p24 *PW* July 2013).

Next we're down to specifics, the circuitry! For the mixer, I chose the MC1496 IC, a favourite of mine. It works well as both transmit and receive mixer and so I used two BT type 47 relays (N17AW from Maplin or similar) to switch the same i.c. from receive to transmit and make the circuit simpler!

The MC1496 works well at the microvolt (μV) input level on receive, and using the a.m. receive head from the articles in Part 1 and 2 in this series provides so much input signal at 20kHz that it's necessary to include a level potentiometer to 'turn it down a bit'!

There's so much gain from the mixer stage that the output signal from the mixer on receive at (3.6MHz) needs attenuation, which also acts as protection for the mixer in case you inadvertently transmit into it! There's so little noise contributed by the mixer to the output that you can hardly hear any increase in noise on the h.f. rig when you power up the transverter – but as

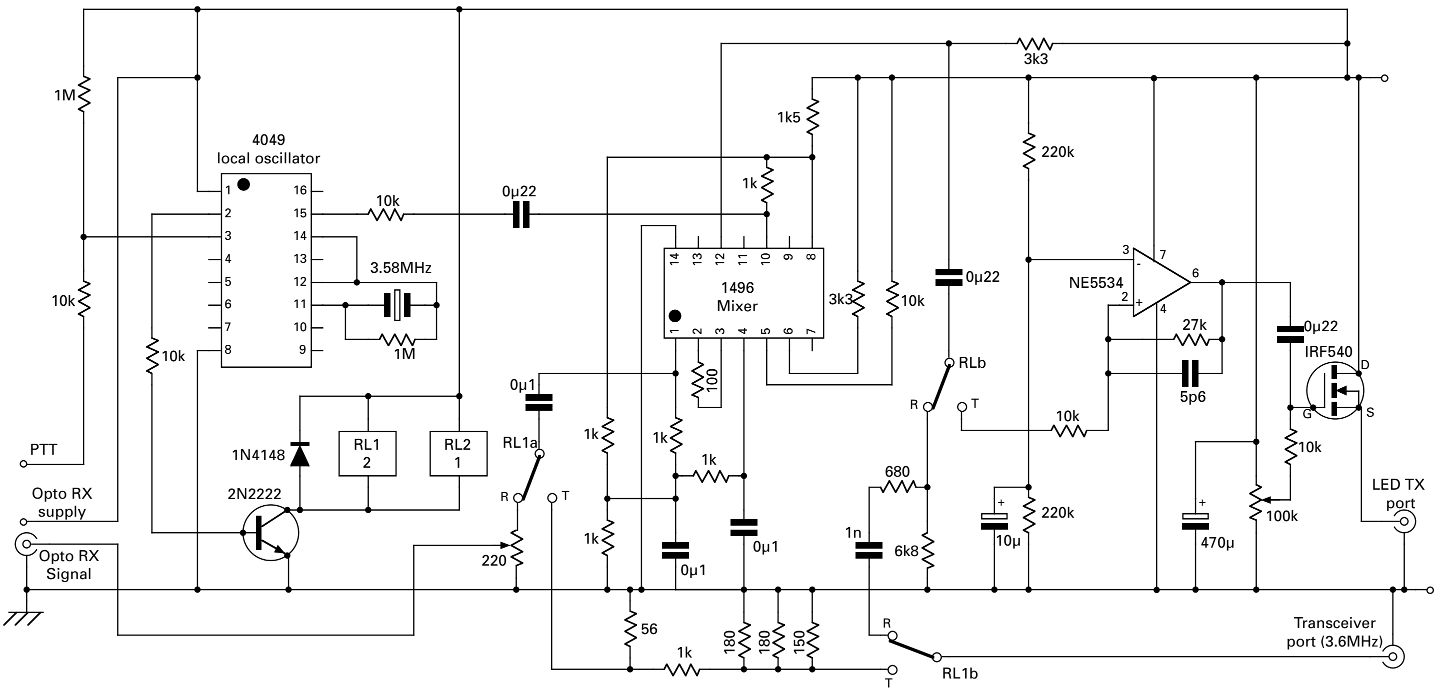


Fig. 5.1: The circuit diagram of Stuart's transverter to fit between his optical transmit /receive heads and his 3.6MHz transceiver.

soon as you connect the receive head to it the noise comes up in a very obvious way.

In practice I then adjust the input level potentiometer so that the h.f. rig S-meter sits just at the bottom of its range when there's no input signal to the receive head. I literally keep it in the dark, literally! That's less noise than if you connect a long wire to use your rig on 3.5MHz!

On the transmit side, when switched by the relays, firstly an attenuator is used to absorb most of the 500mW output of the h.f. rig since only a few mV at 3.6MHz is required by the mixer. Any h.f. rig that can operate at this power level will be okay, if yours has a higher minimum output level than 0.5W, use an external attenuator. If you have a low power transverter output available from your rig, then you may not need this part of the circuit at all.

The mixer then outputs a signal at the sum frequency (7.2MHz – we don't want this) and also at the difference frequency (20kHz, this is the one we want), in the region of a volt more or less, and needs to be boosted a bit, and that's where the op-amp comes in with a voltage gain of just 2.7.

As is my usual approach, I get another useful function from this op-amp circuit due to the feedback capacitor. This turns the op-amp circuit into an active low-pass filter to remove the unwanted 7.2MHz output.

The signal from the op-amp is then used to drive the m.o.s.f.e.t. This device can happily produce currents up to and

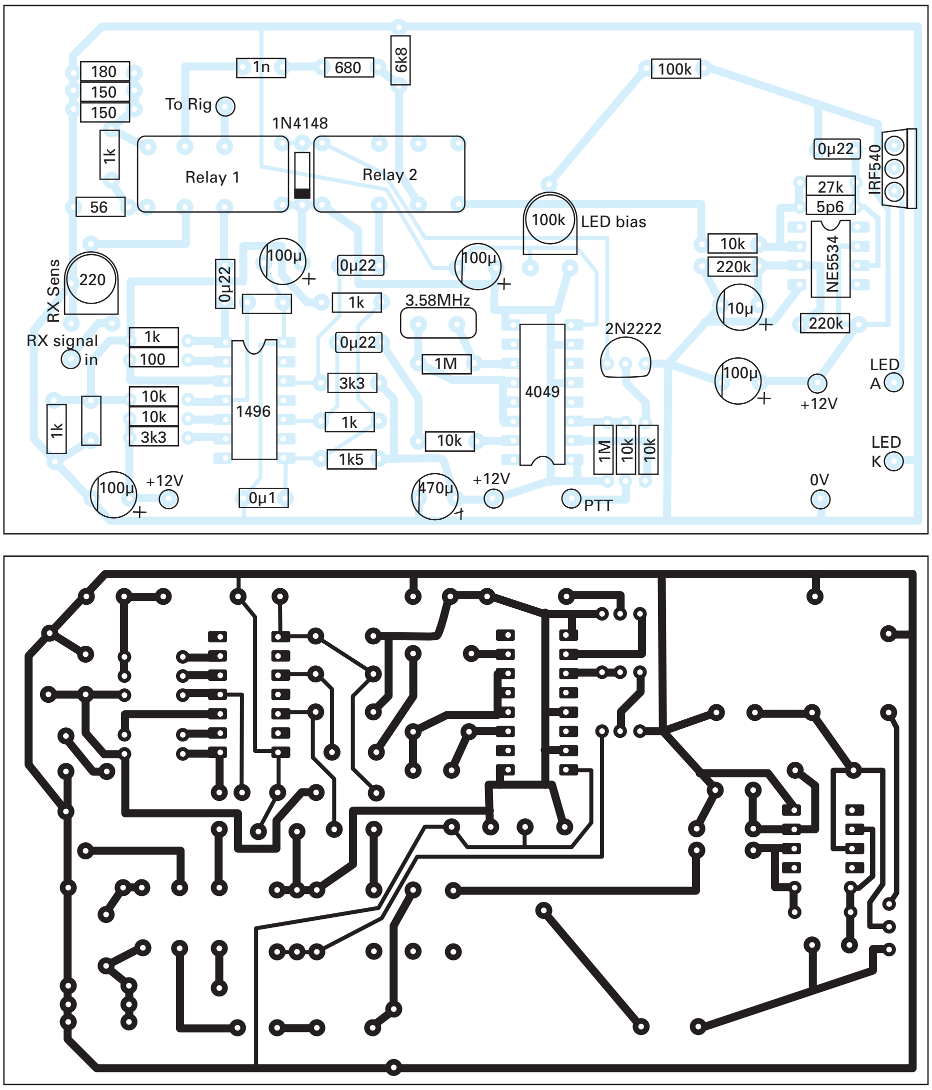
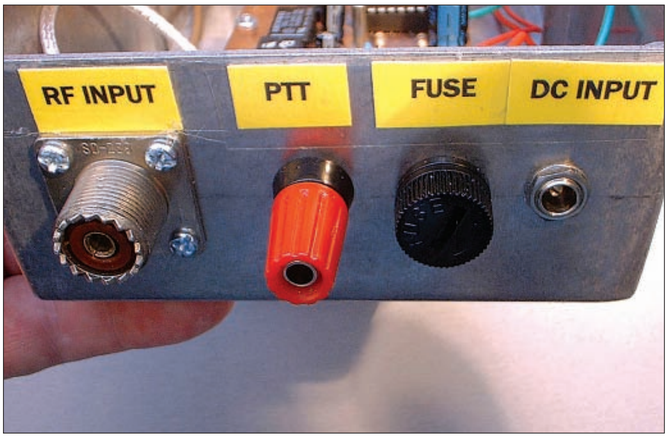
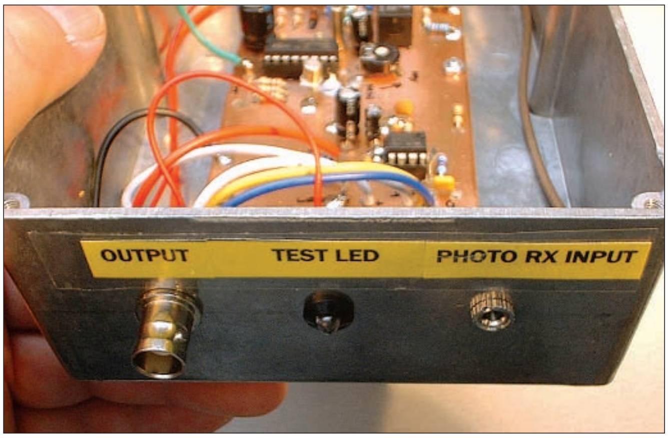


Fig. 5.2: The layout for the transverter developed by Stuart. There are additional 100µF decoupling capacitors, in this layout.



The coaxial output to the rig tuned to to 3.6MHz. Note the supply fuse that's not shown on the diagram of Fig. 5.1, but it can help protect the driver and the l.e.d.



At the other end of the box, are the connections to the optical transmit/receive head. The test l.e.d. can act as confirmation that the transmit side is working.

above 2A to drive a high power l.e.d. via a low value resistor as I've shown you before to produce the optical signal on transmit. There's a bias potentiometer connected to the m.o.s.f.e.t. to set the standing current through the l.e.d.

I also have a low power 5mm l.e.d. on the front panel of the transverter box, driven by the m.o.s.f.e.t. This produces a low power optical signal for bench testing and simply to tell you that you are transmitting!

Tuning the h.f. rig to 3.600MHz results in sub-carrier input and output translated in frequency down to 20kHz. During my development experiments I've used various sub-carrier frequencies ranging from less than 10kHz (tune the rig down to 3.590MHz) up to 30kHz (tune the rig up to 3.610MHz). The transverter is usable over a wider range than this – but the range around 10kHz to 20kHz seems to give good results so that's what I use mostly.

So that's it, a logic chip for receive/transmit switching and local oscillator, one mixer chip, one op-amp, a switching transistor for the relays, and a m.o.s.f.e.t. to drive the l.e.d. makes just five active devices! However, you may have noticed I've not mentioned tuning anything up yet, because there's nothing to tune!

Look back at the block diagram of the basic signal paths of the transverter Fig. 4.5 p24 *PW* July 2013 issue, which describes the overall plan of the signal paths in the transverter. Do this before you look at the circuit diagram, **Fig. 5.1**, and the p.c.b. and component overlay diagrams, **Fig. 5.2**. (These contain some extra 100µF de-coupling capacitors due to the need to have three separate +12V connections).

Early Version Of The Circuit

The photos shown on these pages, are of an early version of this circuit built by **Brian Fothergill G8KPD** and how it's boxed, with some slight differences from the final and better design shown here. My own version is a tatty mess after several modifications! (but it works well!). Note the m.o.s.f.e.t. is mounted using the box as a heat-sink.

On the back of the box the S0239 socket is for the h.f. rig connection, a 4mm socket for the push-to-talk (p.t.t.) line, the power input socket is here along with a 1A fuse in the power line. On the front of the box the BNC socket goes to the transmit head with its high power l.e.d. and series resistor. The test l.e.d. is wired to this socket in series with a 1kΩ resistor (it's not on the p.c.b.). The 3.5mm stereo jack socket is for the power and signal to and from the receive head.

After assembling the circuit and installing it into a suitable screened box, turn the receiver input level potentiometer fully up (clockwise), and the m.o.s.f.e.t. bias potentiometer right down to 0V (anti-clockwise, **very important!**). Next, connect up your h.f. rig, not forgetting the push to talk (p.t.t.) line, the transverter needs an input which goes to 0V to be switched to transmit, such as is provided by most h.f. rigs from a socket at the rear of the rig, as on my FT-817.

Connect up the receive and transmit heads as described earlier, power up the transverter via an ammeter in the +12V line. Then you'll be ready to adjust the potentiometers!

Monitor the current drawn by the transverter on receive, it should be just a few milliamperes on the 12V supply it requires. If you have the receive head connected with the h.f. rig set to 3.600MHz on lower sideband (l.s.b.), there should be noise coming out of the loudspeaker and the S-meter will be indicating well up its scale.

You should then adjust the receive sensitivity potentiometer on the transverter board down until the reading on the S-meter reduces to S0 or near. This is dependent on the light level reaching the receive head photo diode, so it should be kept in the dark for this adjustment. Placed back in daylight and you should see this register on the S-meter as an increased reading.

Switch to transmit and the current drawn will increase due to the relays. With a power l.e.d. connected to the output (and the monitor l.e.d. if fitted), you should notice that initially they are off due to the bias potentiometer being set to 0V.

Gradually increase the bias voltage until the l.e.d. illuminates and the total power consumption rises to the region of 100mA. This is a low quiescent level needed for what I call 'Class B operation of the l.e.d. As the l.e.d. is a diode, it only responds to the positive half of the full-wave signal from the transverter and produces an optical signal accordingly.

Pulsing Brightly!

When you speak into the microphone, you should see the l.e.d. pulse brightly as your speech is converted to a 20kHz optical signal. The current taken by the transverter will peak up to a much higher value, depending on the type of l.e.d. you use and the value of series resistor, to maybe as much as 1A!

Next, change mode to f.m. (unusual on 3.5MHz, but possible on most h.f. rigs), and the l.e.d.s should light up brightly and produce a steady output due to the characteristics of f.m., with its constant carrier envelope of varying frequency.

This mode of operating in "class B" produces a low level of distortion products on harmonics of the sub-carrier frequency which doesn't impact on the clarity of the signal. This set-up will happily 'talk to' any other 'opto rig', using sub-carrier on any mode or even baseband a.m. by tuning down to zero beat with your transverter local oscillator. Work that one out! ●